Effect of Crown to Implant Ratio and Anatomical Crown Length on Clinical Conditions in a Single Implant: A Retrospective Cohort Study

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ABSTRACT

Purpose: The aim of this retrospective cohort study was to evaluate the long-term influence of the crown-to-implant (C/I) ratio and anatomical crown length on clinical conditions around Astra single dental implants placed in the premolar and molar regions.

Materials and Methods: Seventy-six subjects were selected from patients who had been treated with single Astra implants for replacement of missing premolars and molars. The peri-implant marginal bone level change was assessed 1 year after functional loading and 6 years after functional loading. To predict the peri-implant marginal bone level change using clinical and radiographic data, a multiple linear regression model was applied. The Wilcoxon rank sum test was used to analyze difference median in technical complications.

Results: The C/I ratio and anatomical crown length were not associated with peri-implant marginal bone loss or changes in the bone level at 6 years ($p = .48$, $p = .31$). However, the modified plaque index, modified sulcus bleeding index, and smoking status influenced the peri-implant marginal bone loss ($p < .05$, $r^2 = 0.54$). In addition, the patient with technical complication group did show significantly increased anatomical crown length ($p < .05$)

Conclusions: The higher C/I ratio and anatomical crown length did not increase the risk of peri-implant marginal bone loss during 6 years of functional loading. In addition, higher anatomical crown lengths are associated with higher technical complications.

KEY WORDS: crown-to-implant ratio, marginal bone loss, single implant

INTRODUCTION

Tooth extraction may lead to a reduced vertical bone height, resulting in an unfavorable jaw relationship and the inevitable prosthetic consequences of excessive crown height.[1] Increases in the crown height and in the degree of nonaxial loading of an implant-supported prosthesis amplify the risk of excessive occlusal overload by increasing the moment arm.[2]

Theoretical mathematical models,[3] in vitro studies,[4] animal studies,[5] and short-term human clinical studies[6] have claimed the relationship between crestal bone loss and nonaxial loading. However, the results of long-term clinical reports disagree with these observations.[7] Discrepancies in the findings of short-term and long-term studies may be attributed to the continuous bone remodeling that occurs around dental fixtures.[8] In light of the aforementioned studies, clinicians tend to insert the longest implants possible, presuming that a higher success rate is possible with the use of a lower crown-to-implant (C/I) ratio.

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A recent systemic review showed that the C/I ratio seems to influence neither bone resorption nor implant success rates.[9] Nevertheless, these previous reviews have had several limitations, using different definitions of the C/I ratio, implant designs, surface textures, and configurations. Moreover, the question of how different variables affect the relationship between the C/I ratio and the biological and technical complications of implant-supported restorations remains largely unanswered.

In a recent study, it was found that the anatomical crown length is more important than C/I ratio.[10] Identical values of anatomical crown length and anatomical implant length (15 mm as an example) could be seen as a disadvantage from the viewpoint of anatomical crown length (if the length is over 15 mm for the above example), while it is not disadvantageous from the viewpoint of C/I ratio (C/I ratio is 1 in the above example of identical anatomical crown length and anatomical implant length of 15 mm). The anatomical crown length is defined as the distance between the alveolar bone crest and the occlusive plane. The biomechanics of the anatomical crown length are related to lever-arm mechanics[11]: Nonaxial loading creates a significant lateral moment that increases in proportion to the increase in the anatomical crown length, resulting in stress concentration at the implant neck. This bone stress eventually resulted in technical complications of the prosthetic components in in vitro study.[10] Many studies on the clinical performance of implants have reported C/I ratio, but few have considered the anatomical crown length and their influences on the outcomes of implant treatment.

The aim of this study was to evaluate the long-term influence of the C/I ratio and anatomical crown length on clinical conditions around Astra single dental implants placed in the premolar and molar regions.

MATERIALS AND METHODS

Patient Selection

This retrospective study was approved by the Institutional Review Board of Yonsei University. Patients were informed in detail about the study procedures, and all participants signed an informed consent form.

Between January 2003 and May 2005, 76 subjects (40 males) with a mean age of 56 (range: 39–71 years) were selected from among patients who were treated with single Astra implants for the replacement of missing premolars or molars at the Department of Periodontology, Gangnam Severance Dental Hospital. All implants demonstrated at least 6 years of follow-up. All patients had the ability to understand and perform the oral hygiene maintenance procedures as instructed. Exclusion criteria were untreated chronic, aggressive periodontitis,[12] bruxism/parafunction, poor oral hygiene,[13] heavy smokers (>10 cigarettes per day), bone grafting in conjunction with implant placement, multiple implant placement, and uncontrolled systemic disease.

Implants

Ninety-one single internally hexed implants (AstraTech ST™, Astra Tech Dental Implant System, Astra Tech AB, Mölndal, Sweden) were used to replace missing premolars and molars in participants. All implants had a microthreaded cervical neck, TiO_2-blasted surface, and internal hexagonal interface. The 91 implants included 45 implants with a straight-shaped configuration (diameter: 3.5 or 4.0 mm) and 46 implants with a conical neck-shaped configuration (diameter: 4.5 or 5.0 mm). The implant length varied between 8 and 13 mm (Table 1).

Treatment Procedure

All surgeries were performed by a two-stage method. The second surgery was performed 3 or 6 months after the first surgery for mandibular or maxillary implants, respectively. Prostheses were delivered 3 weeks after the second surgery. Patients were recalled every 6 months for professional plaque control and oral hygiene evaluation.

Radiographic Examination and Evaluation

Two possible C/I ratios were defined: the anatomical C/I ratio and the clinical C/I ratio (Figure 1). For the anatomical C/I ratio, the fulcrum was positioned at the most coronal bone-implant contact. For the clinical C/I ratio, the fulcrum was established at the interface between the implant shoulder and the crown-abutment complex. Because the anatomical C/I ratio seems to describe a more plausible biomechanical scenario than the clinical C/I ratio for evaluating the effect of the C/I ratio on implant-supported prosthesis complications, the anatomical C/I ratio was applied to the linear measurements in the present study.

TABLE 1 Regression for Demonstration of Factors Influencing the Peri-Implant Marginal Bone Loss

Variables	Coefficient(β)	SE	*t* Ratio	*p*
C/I ratio	0.291	0.086	0.128	.482
Anatomical crown length	0.257	0.084	3.037	.314
Anatomical implant length	0.0681	0.016	0.0046	.67
Implant diameter	0.008	0.0043	0.191	.84
Implant location	0.598	0.072	8.233	.644
mPI	1.152	0.033	0.274	<.05
mSBI	1.891	0.031	0.463	<.05
Smoking status	0.307	0.0057	1.142	<.05

Multiple linear regression test for $p < .05$.
Adjusted $r^2 = 0.544$; sum of squares, 695.96; SD of residuals, 3.742; $F = 11.253$.
C/I = crown-to-implant; mPI = modified plaque index; mSBI = modified sulcus bleeding index; SD = standard deviation; SE = standard error of the estimate.

Figures 2 and 3 show the linear measurements that were obtained between landmarks. Radiographs were taken with an extension cone paralleling device (Extension Cone Paralleling Kit, Rinn, Elgin, IL, USA) by the parallel cone technique (70 kV, 8 mA, 0.250 s). A 5.5-mm spherical metal bearing was placed to aid length measurement. All films were developed with the same automatic processor (Periomat, Durr Dental, Bietigheim-Bissingen, Germany) according to the manufacturer's instructions. Films were digitized with a digital scanner (EPSON GT-12000, EPSON, Nagano, Japan) at an input resolution of 2,400 dpi with 256 gray scale. Periapical radiographs (Kodak Insight, film speed F, Eastman Kodak Co., Rochester, NY, USA) were taken 1 day after implant placement, immediately before the second surgery, immediately after prosthesis delivery, 1 year after functional loading, and at the annual follow-up visit.

Measurements were taken to the nearest 0.1 mm (the intraclass correlation coefficient value of reliability was 0.913) with the Image J 1.43u software package

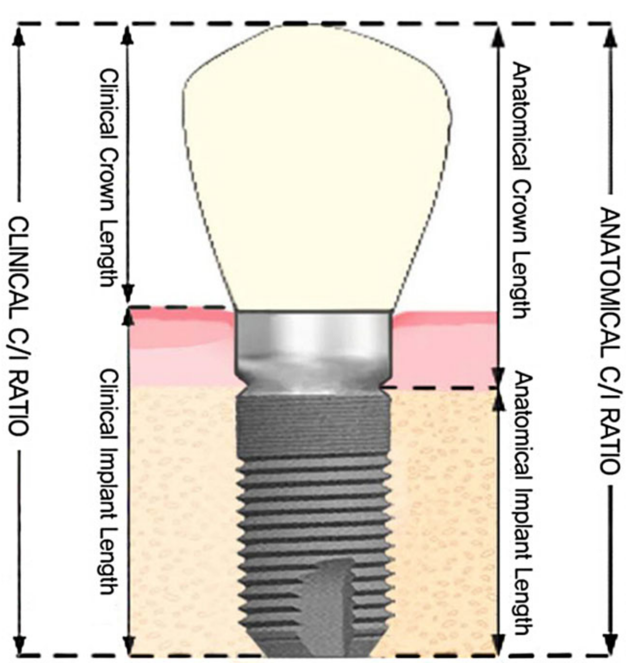


Figure 1 Anatomical crown-implant ratios and clinical crown-implant ratios.

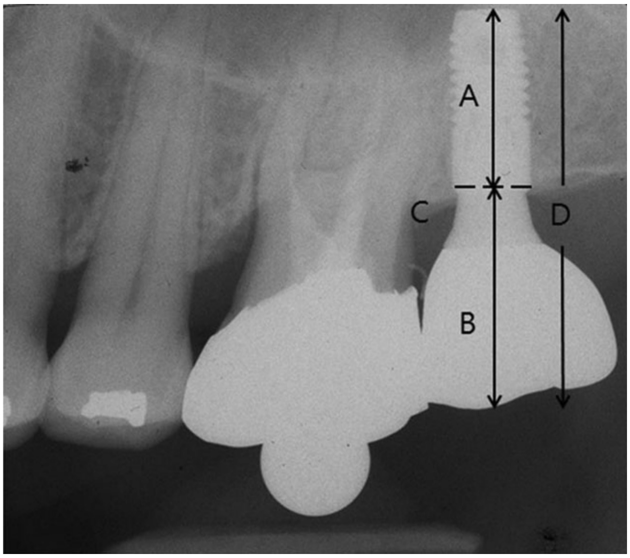


Figure 2 *A*, Anatomical crown length (ACL): perpendicular distance from the implant shoulder to the most coronal aspect of the crown. *B*, Anatomical implant length (AIL): perpendicular distance from the implant shoulder to the most apical aspect of the implant. *C*, Crestal bone level (CBL): perpendicular distance from the implant shoulder to the first visible apical bone to implant contact in the mesial and distal aspects of the implant. *D*, ACL/AIL ratio (C/I ratio).

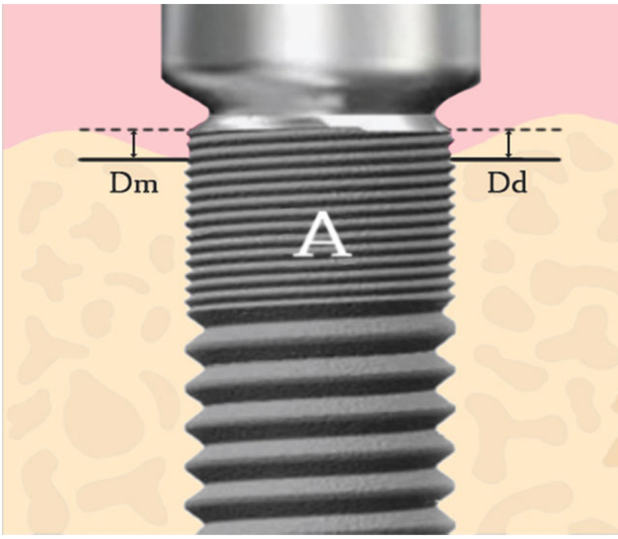


Figure 3 Schematic representation of the site and reference point measurements. A, AstraTech ST™ 4.0 s implant. Solid line indicates the measurement site. Dm and Dd, distance from the reference point to the marginal bone at the mesial and distal parts of the 4.0 s implant, respectively.

(Wayne Rasband, National Institutes of Health, Bethesda, MD, USA). Calibration was performed by using the known distance of the spherical metal bearing (5.5 mm). The peri-implant marginal bone level change was measured by comparing radiographs taken immediately after and 6 years after prosthesis delivery.

The reference point was defined as the border between the polished surface and the rough surface of the fixture (Figure 4). The marginal bone levels at the mesial and distal implant surfaces were assessed by measuring the distance between the reference point and the most apical point of the bone level; these values were then averaged. The precision of the radiographic measurements was calculated by comparing the values of the first and second radiographic readings. Calibration and standardization were performed.

Technical Complications

During the examination, the implant-supported single crown was also examined for any complications.

Technical complication included:

- loss of retention;
- fracture and/or chipping of ceramics;
- fracture of the framework;
- loosening of an occlusal screw;
- fracture of an occlusal screw;
- loosening of an abutment;
- fracture of an abutment;
- fracture of an implant.

Soft Tissue Parameters

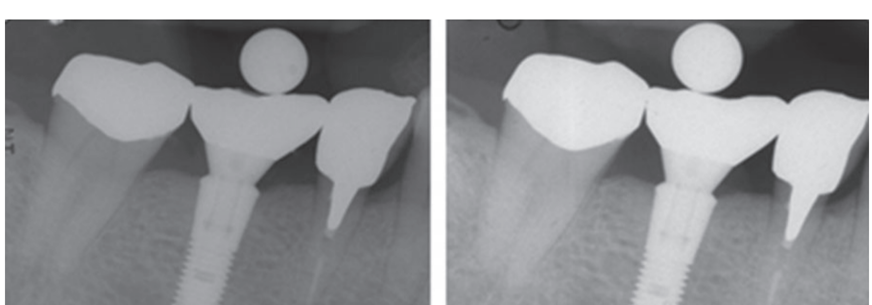
Patients were evaluated for pain, discomfort, and implant-related infection annually. To rule out the possible influence of inflammation of the peri-implant soft tissues on the surrounding marginal bone, the modified plaque index (mPI) and modified sulcus bleeding index (mSBI) were measured at four aspects around each implant.[13] Averages of the four measured mPI and mSBI values were calculated.

Statistical Analysis

The Shapiro–Wilk test was used to test the normal distribution of variables.

A multiple linear regression model was used to predict the peri-implant marginal bone level changes measured by radiographic and soft tissue parameters.

Pearson's correlation analysis was used to test the relationship between the anatomical crown length and soft tissue parameters.



A B

Figure 4 Periapical radiographs taken (A) immediately after and (B) 6 years after prosthesis delivery.

TABLE 2 Characteristics of Patients with Technical Complications and Patients without Technical Complications according to the Anatomical Crown Length

Characteristic	With Technical Complications (n = 12)	Without Technical Complications (n = 79)
ACL (mm)		
Median	15.14	10.74
Range	12.52–18.19	9.3–11.89

Wilcoxon rank sum test for $p < .05$.
ACL = anatomical crown length.

Nonparametric Wilcoxon rank sum test was used to analyze the medians of anatomical crown length in view of technical complications.

Statistical software (SPSS for Windows, version 17.0, SPSS Inc., Chicago, IL, USA) was used to process all data. Values were deemed statistically significant if the p value was less than .05. For peri-implant soft tissue parameters, the sample was divided into implants that gained or lost bone. The change in these parameters from the initial to the final examination was calculated for each group.

We tested three hypotheses in our study: (1) C/I ratio and anatomical crown length do not affect peri-implant marginal bone loss. (2) There is no correlation between anatomical crown length and soft tissue parameters. (3) There is no difference between the two groups in technical complications.

RESULTS

Effect of C/I Ratio and Anatomical Crown Length on Peri-Implant Marginal Bone Loss

Multiple linear regression analysis showed that C/I ratio and anatomical crown length were not associated with peri-implant marginal bone loss at 6 years. However, as it is shown in Table 1, we found that mPI, mSBI, and smoking status significantly influence peri-implant marginal bone loss.

Technical Complications

Technical complications were observed in 12cases of the single implant restorations (13.1%). These cases include six implants with screw looseness (6.6%), three implants with porcelain fracture (3.3%), and three separate cases of loss of retention, screw fracture, and fixture tearing (1.1% each). As it is shown in Table 2, Wilcoxon rank sum test found that patients with technical complication have significantly higher anatomical crown lengths (<.05).

Evaluation of Soft Tissue Near the Implant

The peri-implant soft tissues were clinically healthy. The average mPI and mSBI values (mean ± standard deviation) were 0.46 ± 0.16 and 0.44 ± 0.11, respectively. As it is shown in Table 3, Pearson's correlation analysis revealed a positive correlation between anatomical crown length and soft tissue parameters.

DISCUSSION

In this study, we investigated the long-term influence of C/I ratio and anatomical crown length on the clinical conditions of homogenous implant-supported single crown restorations in the posterior segments of jaw. Our results show that C/I ratio and anatomical crown length are not associated with peri-implant marginal bone loss or changes in the bone level at 6 years. Using multiple linear regression analysis, it was shown that mPI, mSBI, and smoking status influence the peri-implant marginal bone loss. This model explains the 54% observed variability. In addition, higher anatomical crown lengths are associated with higher technical complications.

Infection was carefully controlled throughout the follow-up period to prevent peri-implant marginal bone

TABLE 3 Correlation between Anatomical Crown Length and Soft Tissue Parameters

	mPI	mSBI
ACL	r = 0.74	r = 0.68

Pearson's correlation test for $p < .05$.
ACL = anatomical crown length; mPI = modified plaque index; mSBI = modified sulcus bleeding index.

loss because of bacterial biofilm formation and consequent inflammation. Levels of plaque accumulation and sulcus bleeding were compared between the two groups. Patients with poor oral hygiene were excluded from this study. To minimize bias, only implant-supported single crown restorations were included in the analysis. Moreover, only restorations in the posterior segments were chosen because it is assumed that these restorations undergo higher occlusal forces and, therefore, have a higher potential risk for complications.[14]

The fixtures used in this study had the same surface treatment (AstraTech ST), implant-abutment interface (Conical Seal Design™, Astra Tech AB, Mölndal, Sweden), and thread characteristics. The only different characteristic was the fixture design. This is not likely to influence our results because a recent study showed that the use of implants with different gross fixture designs (e.g., conical neck vs straight implants) did not result in different marginal bone losses after 1 year of loading.[15]

In our study, the overall level of crestal bone loss was very small (1.0 ± 0.2 mm). The mean marginal bone loss was well below 1 mm after 5 years for the Astra Tech implants. This corresponds to an annual mean bone loss of 0.05 mm, which should be compared with present success criteria that allow for 1 mm bone loss during the first year, and further annual loss not exceeding 0.2 mm that in sum corresponds to 1.8 mm over 5 years.[16]

No relationship was found between C/I ratio and the bone level change at 6 years ($p = .48$), which is consistent with the findings of previous studies.[9,14,17] The stress level of implants with off-axial loading was within the load-bearing capacity of the surrounding bone. The stress concentration at the bone crest induced by the masticatory forces may stimulate bone formation around some fixtures.[8]

In a previous study, anatomical crown length was claimed to be more important than C/I ratio in assessing biomechanical-related effects.[11] However, no relationship was found between the anatomical crown length and the bone level changes at 6 years ($p = .31$) in our study. This could be due to the fact that some features of the implant may have exerted beneficial effects on the maintenance of the marginal bone level[18,19] (e.g., rough surface, conical fixture-abutment interface, and microthreading), which may have overwhelmed the effects of the high C/I ratio and anatomical crown length.

Although C/I ratio and anatomical crown length may not affect the peri-implant bone loss, it has been hypothesized that implant restorations with high anatomical crown length overload the prosthetic components, which increase the risk of technical complications such as screw fracture, screw looseness, loss of retention, and veneering fracture. In our study, we found that anatomical crown length and technical complication are significantly associated ($p < .05$). This is consistent with the findings of previous studies.[10,20]

Using multiple linear regression analysis, it was shown that mPI, mSBI, and smoking status influence the peri-implant marginal bone loss. This model explains the 54% observed variability. We found that mPI and mSBI are significantly correlated with peri-implant marginal bone loss (both p values $< .05$). An increase in dental plaque accumulation leads to a greater inflammatory response in the peri-implant soft tissues, which is measured by sulcus bleeding. Inflammation of the peri-implant tissues increases the risk of peri-implant marginal bone loss. This observation is in agreement with previous studies;[21,22] however, our mPI and mSBI scores are low (scores of 0 and 1),which could be explained by infection control.

We also found that smoking status is significantly correlated with peri-implant marginal bone loss ($p < .05$). Smoking has been shown to have detrimental effects on both osseointegration and maintenance of crestal bone.[23,24] Our results indicate that smokers have a greater tendency to lose crestal bone although this trend did not reach a significant level. It should be noted that most smokers in our study are light smokers (no more than 10 cigarettes per day) and that they only constitute 14.3% of our cases.

Additionally, we found that anatomical crown length and soft tissue parameters are positively correlated ($p < .05$, mPI $r = 0.074$, mSBI $r = 0.68$). The sulcular brushing technique requires that the toothbrush be placed at the gingival margin. Short implants combined with a long suprastructure make the toothbrush less accessible, and successful oral hygiene is reached with more difficulty. This facilitates bacterial biofilm formation and leads to intense gingival inflammation.[25]

Posterior placement of the implant can be complicated by other physical conditions such as a limited vertical bone height because of expansion of the maxillary sinus or proximity to the inferior alveolar nerve. In a recent systemic review, prostheses supported by short implants were shown to have high survival rates and low incidence rates of biological and biomechanical complications. These prostheses could be a valid option for the prosthetic treatment of atrophic alveolar ridges and may provide surgical advantages including reduction in morbidity, treatment time, and costs.[26] Meanwhile, outcome of shorter implants should be approached with caution. Findings of another systemic review add to the growing evidence that short implants (<10 mm) in partially edentulous patients show a negative significant association with failure rate and implant length, that is, the longer the implant, the higher the implant survival rate within the length range of 5 to 8.5 mm. Furthermore, this review demonstrated a trend for increased failure of short implants in smokers (more than 15 cigarettes per day).[27]

One of the drawbacks of our study is the narrow distribution of C/I ratio. Although it might not be ethically justifiable, it is feasible to insert short implants with unfavorable C/I ratios. We analyzed a previous study comparing implant restorations with a C/I ratio >2 and found that a higher C/I ratio did not influence the survival rate or marginal bone loss.[28] Other limitations of our study include small sample size and possibility of false diagnoses when analyzing small peri-implant bone-level changes.[29]

CONCLUSIONS

C/I ratio and anatomical crown length are not associated with peri-implant marginal bone loss after 6 years of functional loading; however, higher anatomical crown lengths are associated with higher technical complications.

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